

CLAIMS

1. Process for the balanced charging of n cells, with $n \geq 2$, constituting a lithium ion or lithium polymer battery and associated in series, each cell being comprised by one or several elements mounted in parallel, which process is characterized in that it consists in providing continuously, from the onset of the charging operation of the battery (2) and throughout the course of this operation, a surveillance of the levels of charge of the different cells (1), and in carrying out, as a function of the mentioned evaluation of said charge levels, either a uniform supply of all the cells (1), or a balancing of said charge levels of said cells (1) by supplying these latter in a differentiated manner as a function of their current levels of charge.

2. Process according to claim 1, characterized in that it consists in triggering for each cell (1) of the battery, one after the other, in a sequential manner, for a fractional portion of the total charge time of the battery (2), sequences comprising a refreshed evaluation of the level of the charge of the cell (1) in question, followed, as a function of its level of charge and with respect to all the levels of charge of the other cells (1) of the battery, a uniform or differentiated supply, this according to a repeating cycle throughout the operation of charging.

3. Process according to claim 1 or 2, characterized in that it comprises at least the execution of the following operations under the management of a digital

processing unit (3), and this from the beginning of charging:

- evaluation, preferably at regular intervals, of the quantity of energy stored in each cell (1) by measuring a parameter indicative of said quantity;
- comparative analysis of the different evaluated quantities of energy or of the different values of the measured parameter for each cell (1);
- determination of the cell (1) tardiest to charge and, as the case may be, of the cell or cells (1) the most advanced in charging;
- supplying the different cells (1) mounted in series in a uniform manner or with the limitation of charging current for the cells (1) other than the tardiest or for the cell or cells most advanced in charging, by derivation of all or a portion of said current at the level of this or these latter;
- sequential repetition of the different mentioned operations obtaining an end condition of charge of the battery (2) or the detection of a fault, of a dysfunction or an exceeding of an admissible threshold value.

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4. Process according to claim 3, characterized in that the measured parameter in each cell (1) and utilized for evaluation of the quantity of energy stored in this latter, is the voltage at the terminals of the cell (1) in question.

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5. Process according to claim 3 or claim 4, characterized in that the derivation of current in the cell or cells that are most advanced in charging, is carried out by a means of derivation circuits (4) each associated by mounting in parallel with one of said cells (1), said circuits (4) each integrating a switching member (5) and, as the case may be, at least one component for dissipation of energy (6), if desired adjustable, such as for example an electrical resistance.

6. Process according to claims 4 and 5, characterized in that charging with sequential balancing consists more precisely in carrying out, while repeating them during the course of charging the battery (2), the following operations:

- a) scrutinizing one by one all the cells (1) of the battery (2) by measuring the voltages at their terminals, this without the resistances (6) of derivation or balancing being connected;
- b) detecting the cell (1) tardiest to charge;
- c) detecting the cells (1) which, relative to the least charged or tardiest cell (1), have an overcharge greater than a predetermined threshold value of difference of capacity, for example corresponding to a difference of voltage (dVs) of 10 mV;
- d) individually connecting each cell (1) detected to have a surcharge greater than a threshold value, to a corresponding balancing resistance (6) so as to produce a decrease of the charging current for each of the cells (1) in question, for example of about 10%, during a

predetermined sequential duration, for example two seconds;

e) disconnecting the balancing resistances (6) of all the cells (1) after lapse of the predetermined sequential duration;

f) carrying out again steps a) to e) after the elapse of a stabilization delay of the voltages of the cells (1).

7. Process according to any one of claims 1 to 6, characterized in that the charging of the battery (2) is normally stopped when the current intensity of the overall charge of the assembly of cells (1) of this latter descends below a predetermined threshold value, for example 50 mA.

8. Process according to any one of claims 5 and 6, characterized in that the voltage at the terminals of each cell (1) is measured precisely by an assembly (7) of corresponding measurement modules (7'), whose output signals are transmitted, preferably after digitization, to the digital processing unit (3), this latter controlling, in the following cycle, the switching members (5) of the different derivation circuits (4) as a function of the comparative development of said output signals provided by the modules (7').

9. Process according to any one of claims 3 to 6, characterized in that the operations are repeated, during all the charging operation, as a cyclic loop formed by two operational half cycles, carried out successively at each cycle loop, a first half cycle comprising the consecutive execution of the following operations: successive reading

of the voltages of the different cells (1) and triggering, offset in time, the balancing resistance (6) for each cell (1) whose voltage difference (dV) with the tardiest cell of the preceding cycle is greater than a threshold value (dVs), and the second half cycle comprising the following operations: successive disconnection of the balancing resistances (6) of the different cells (1) and waiting for the stabilization of the voltages of the different cells (1) before their reading during the first half cycle of the following cycle, the two half cycles preferably having substantially similar durations, for example about 2 seconds.

10. Process according to claim 9, characterized in that the threshold value of voltage difference (dVs) consists in a first predetermined fixed value (V1), for example 10 mV, if the voltage difference (dV) between the voltage of the cell (1) having the highest voltage and the voltage of the cell (1) having the least voltage is less than a second predetermined fixed value (V2), greater than the first predetermined threshold value (V1), for example 100 mV.

11. Process according to claim 10, characterized in that, if the voltage difference (dV) between the voltage of the cell (1) having the highest voltage and the voltage of the cell (1) having the lowest voltage is greater than a second predetermined fixed value (V2), for example 100 mV, the threshold value of voltage difference (dVs) consists of a third predetermined fixed value (V3) less than said second value (V2), for example 30 mV.

12. Process according to claims 10 and 11, characterized in that the third predetermined fixed value (V3) is greater than said first predetermined fixed value (V1).

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13. Process according to claim 9, characterized in that the threshold value of the difference of voltage (dVs) corresponds to a given fraction of the voltage difference (dV), measured during the preceding cycle between the voltage of the cell (1) having the highest voltage and the voltage of the cell (1) having the lowest voltage, if during the cycle taking place, said voltage difference (dV) is still higher than a fourth predetermined fixed value (V4), for example 10 mV.

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14. Process according to any one of claims 9 to 13, characterized in that the measurements of the voltages of the different cells (1) are carried out only after the elapse of a give delay, for example 2 seconds, following the suppression of the current derivations, so as to permit stabilization of the voltages at the terminals of said cells (1).

15. Process according to claim 5 or any one of claims 6 to 14, taken in combination with claim 5, characterized in that the powers of the different derivation circuits (4) are selected to be near the values provided by the formula:

$$Psd \max = \frac{V \max \text{ cell} * \% * AH}{Tc}$$

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in which:

Psd max = maximum power optimized to dissipate,
expressed in watts;

Vmax cell = maximum voltage measured during charging
at the terminals of a cell, expressed in
volts;

% = ratio expressed in percentage, corresponding to
the maximum difference between two cells to
compensate during charging;

AH = nominal capacitance of the battery expressed in
Ah (Ampere-hours);

Tc = battery charge time expressed in hours.

16. Process according to any one of claims 3 to 15,
characterized in that it consists, at the outset, before
triggering the execution of the operations, in measuring
the standby voltage (Vo) of a charger (8) connected to the
battery (2) as to its charge, and stopping said charging
process with if desired the triggering of a corresponding
arm and/or display of a message, if said standby voltage
(Vo) is greater than [n x maximum admissible voltage (Vmax)
for each cell (1)].

17. Process according to any one of claims 9 to 16,
characterized in that it consists, before the execution of
a following loop, in verifying whether at least one of the
cells (1) of the battery (2) has at its terminals a voltage
higher than the maximum admissible voltage (Vmax) and, in
the affirmative, in interrupting the process of charging,
if desired with the triggering of a corresponding alarm
and/or display of a message.

18. Device for the practice of a process according to any one of claims 1 to 17, characterized in that it is essentially constituted, on the one hand, by an assembly (7) of modules (7') for measuring the voltage associated
5 each with one of the cells (1) in series forming the battery (2) and measuring the voltages at the terminals of these latter, on the other hand, by a plurality of derivation circuits (4) each mounted in parallel with the terminals of a corresponding cell (1) and each being
10 adapted to be opened and closed selectively, and, finally, by a digital processing unit (3) for managing the process, said unit (3) receiving measurement signals from said assembly (7) of measuring modules of the voltage (7') and controlling the condition [closed/open] of each derivation
15 circuit (4).

19. Device according to claim 18, characterized in that each derivation circuit (4) comprises a switching member (5), forming a switch whose condition is controlled
20 by the digital processing unit (3) and, as the case may be, at least one component (6) for dissipation of electrical energy, such as for example one or more resistances.

20. Device according to any one of claims 18 and 19,
25 characterized in that the assembly (7) of modules (7') for measurement of the voltage comprises, on the one hand, n analog modules (7') for measuring the voltage, each associated directly with a cell (1) of the battery (2), on the other hand, in a multiplexing circuit (9) whose inputs
30 are connected to the outputs of said modules (7') and, finally, an analog/digital converter circuit (10) connected at its input to the output of the multiplexer circuit (9)

and at its output to the digital processing and management unit (3).

21. Device according to any one of claims 18 to 20,
5 characterized in that it is integrated into an assembly of
a self-contained electric power tool.